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A CONCISE HISTORY OF DUTCH RIVER FLOODS

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Abstract. Based on a brief account of 1,000 years of river floods and flood management in the Dutch Rhine delta, it is argued that vulnerability to river floods depends on the complex interaction of economics, institutions, politics and, to a limited extent, climate. Response functions and thresholds for climate change impacts should take this complexity into account rather than assuming society to be constant or evolving in a straightforward manner.

1. Introduction

This paper focuses on the 1,000 year history of the struggle of the Dutch people with floods in the Rhine delta (Langen, 1995; Langen and Tol, 1996). It also discusses present and possible future flood hazards (Penning-Rowsell et al., 1996). The main aim is to demonstrate why thresholds and response functions may not be the most appropriate way to describe the complex interactions between climate and society.

The results stem from the climate change and extreme weather events project financed by the European Union Environment and Climate Programme and the Netherlands National Research Programme on Global Air Pollution and Climate Change (Downing et al., 1996). Three insights from this project are restated here. Firstly, using stochastic downscaling techniques, it is possible to explore sensitivities to changes in extreme weather regimes, albeit in a speculative 'what-if' mode. Because extreme weather events occur on a fine temporal and spatial scale, it is hard to capture them in synoptic analyses, such as integrated assessment modeling. Secondly, the European Union is not likely to be strongly impacted through extreme weather events such as wind storms, river floods, or droughts. Current expenditures on protection and damages is low relative to Gross Domestic Product. Even if climate change were to double or triple this, which is not inconceivable, the total figure is still low, and no reason for worry. This is on average. Single years or single places may be bad, but the redistributive fabric of our current society is strong enough to allow for averaging. In general, averaging smooths thresholds, and redistribution lowers relative impacts. On the other hand, extreme weather may trigger political action, and mobilize support for 'structural solutions'. Thirdly, adaptation is an order of magnitude more important than climate. It is the interaction of climate and society that matters, not the action of climate on society.

* Andreas Langen was a student at the University of Münster, visiting IVM with a fellowship of the ERASMUS exchange programme of the Commission of the European Community.

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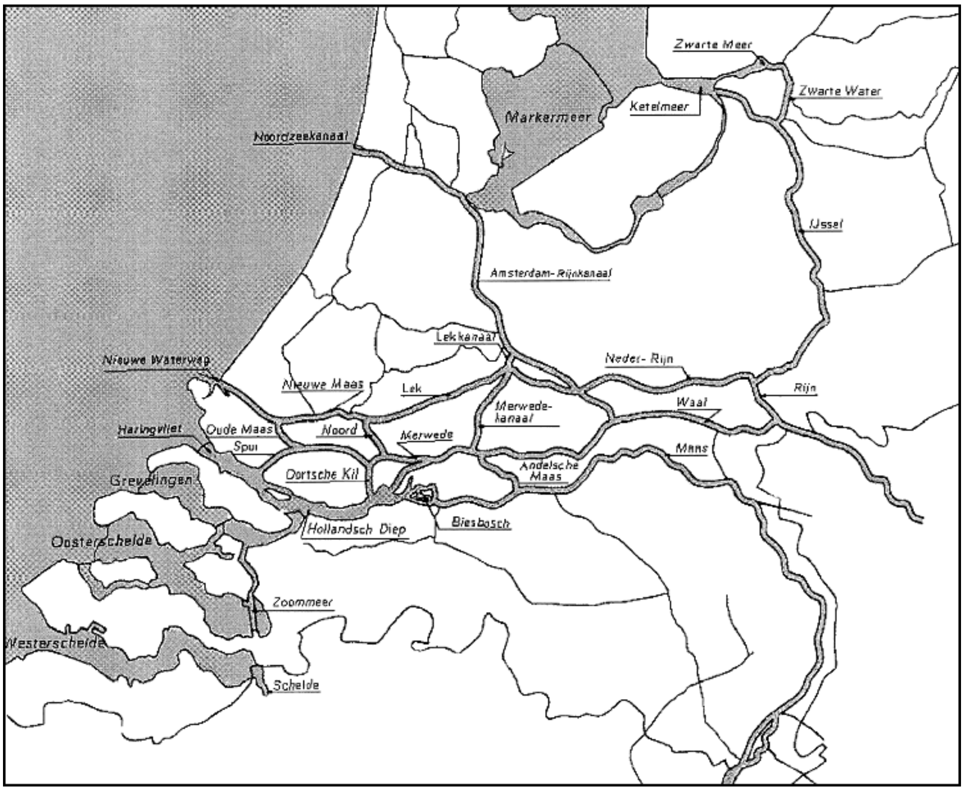

Figure 1. The delta of the river Rhine at present times. Most of the water of the Rhine (Rijn) is discharged through the IJssel, the Netherrhine (Neder-Rijn) - Lek, and the Waal. The Old Rhine mouths between the Nieuwe Waterweg and the Noordzeekanaal; the Old Rhine was a major mouth before the Lek (literally: Leak) emerged. The river Meuse (Maas) is also shown. Source: Van de Ven (1993).

This undermines the concept of climate impact response functions, which presume a regular, constant and one-way relationship between impulse (i.e., change in the natural environment) and response (i.e., change in human welfare).

These points are illustrated with the case of river floods in the Dutch Rhine and Meuse delta. Figure 1 depicts the current situation. The story starts a thousand years ago.

2. The Past of River Floods

A common saying is that God created the world, but the Dutch The Netherlands. This is flattering but false. Stol (1993) argues that the battle of the Dutch against nature is in fact a battle against processes they themselves started earlier. Until the 10th century, the (then few) Dutch dwelt on higher grounds, near to but safe

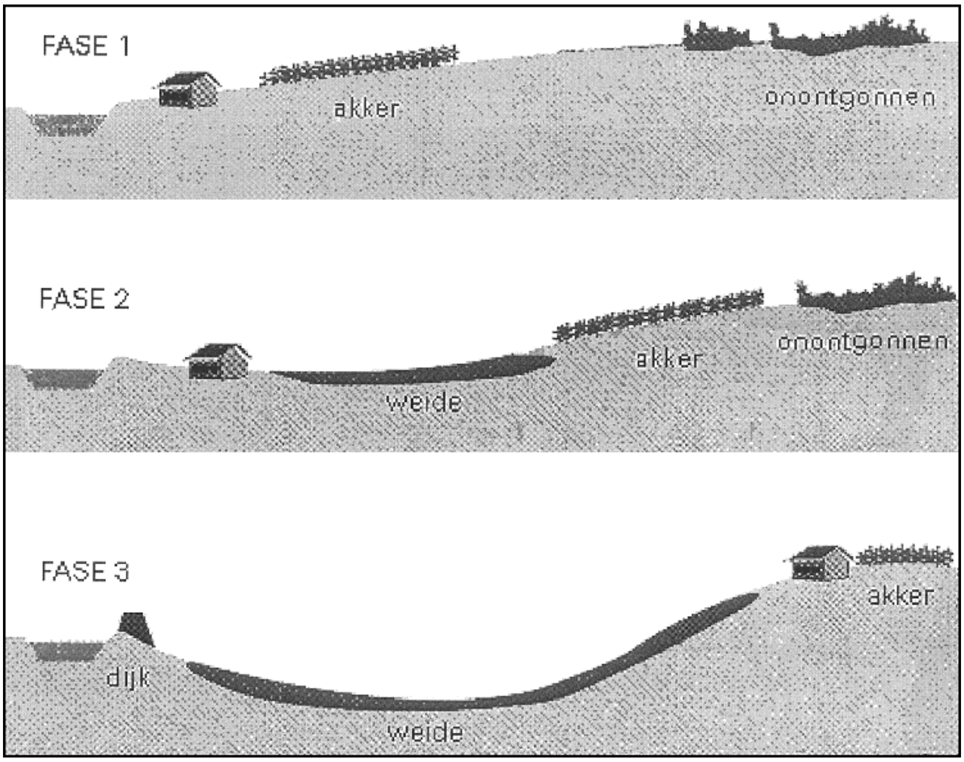

Figure 2. Cross section of a typical Dutch river through history. Cultivation leads to subsidence, so that first arable lands are converted to pasture land, and second dikes need to be built. 'fase' = phase; 'akker' = arable land; 'onontgonnen' = uncultivated; 'weide' = pasture land; 'dijk' = dike. Source: Van de Ven (1993).

from the rivers. The somewhat drier climate during the medieval optimum, greater social stability, newer ploughing techniques and new draining techniques allowed the population to expand and cultivate the many moorlands and fenlands, which it did rapidly, particularly in the county of Holland* and the diocese of Utrecht.

Cultivation required draining of the moorlands, which then still lied well above sea level. Draining led to dehydration and, in turn, oxidation of the high moorlands. Subsequently, settlement and subsidence resulted in a relative rise of sea and river levels. Sea and river level rise implied increased flood risks. Figure 2 depicts the process of cultivation - subsidence - dike building.

Until the 12th century, riverine floods are only sporadically reported in The Netherlands (Gotschalk, 1971), and the sources are doubtful (Van de Ven, 1993). The 12th century, however, was characterized by a series of heavy sea surges that greatly altered the shape of the coast. The number of flood reports gradually in-

* County here means the domain to a count.

creased during the 13th century, and in the 14th century, river floods became a recurrent phenomenon and an acknowledged problem.

The interaction between climate and society was *indirect*. Climate change (i.e., Medieval Optimum) was one of the causes for social change (i.e., population growth). Social change then caused an increase in flood hazards.

Besides increased flood risk, the higher water table hampered draining of tillage fields. This led to a conversion of arable land to pasture land near the coast, and further cultivation upstream. Drainage was needed there as well, and subsidence of the land resulted. River flood risk consequently increased. Additional reasons for increased flood risks are large scale deforestation in Germany and the fact that a dike downstream results in water accumulation upstream in case of high water.

Increased flood risks were followed by flood protection, notably dikes. In the 13th century, the first comprehensive dike systems were built in Holland and Utrecht. The first local 'waterships' were then established.* Waterships are the institutions concerned with water management, including drainage and dike building. Examples of early waterships are *de Lekdijk Bovendams* (south of Utrecht), the *Grote Waard* (south of Gorinchem) and the later *Rijnland* (north of Leiden) which were established prior to 1250.

Occupied as they were with flood safety, the so far relatively independent villages sought legal security and social stability with the count of Holland and the bishop of Utrecht. This is the first sign of how flood risk helped building central authority. In turn, this laid the ground for regional waterships (from 1250 onwards in the west) and the codification of dike maintenance in 'dike letters'.** The oldest known dike letter, for *Heusden* (west of Den Bosch) is dated 1273.

As the floods slowly crept upstream, so did flood control and the corresponding institutions. The establishment of waterships, dike rights, and the centralization of the power of the counts of Gelre and Kleve*** followed about fifty years after the developments in the downstream regions of Holland and Utrecht. The counts of Gelre also introduced 'watercourse letters',‡ written concessions to build draining canals. Watercourse letters thus regulated land cultivation. The first known letter is dated 1316 for the *Tieler- and Bommelerwaarden* (between Den Bosch, Gorinchem and Tiel).

The first half of the fourteenth century saw many disasters all over Europe. The Netherlands were no exception, witnessing the severe floods in 1313 and 1315 and the famine of 1314-1317 killing 5 to 10% of the population. The disastrous

* The Dutch word *waterschap*, here transcribed as 'watership', refers to both the water board and the area resorting under it.

** The Dutch *dijkbrief* is translated as 'dike letter'. Letters by the land lord were then the prime means of establishing laws, regulations, duties, and rights.

*** The countship of Gelre was situated east of Utrecht, north of the rivers; the countship of Kleve was situated further east, extending into what now is Germany. The Netherlands were then part of the Holy Roman Empire.

‡ The Dutch *weteringsbrief* is translated as 'watercourse letter', although the word *wetering* usually means an artificial watercourse to discharge excess water.

situation acted as a catalyst for the further formalization of water control. By 1350, the Dutch river delta had closed dike systems along all major rivers.

The interaction between climate and society was virtually absent. Social dynamics were the main driver for changing hazards, although the end of the Medieval Optimum may have played a role.

The story becomes more complicated after 1350. First some general history. The mutually independent counties were united under Philip the Good of Burgundy in 1433. The mutual independence was largely maintained, however, although the States General provided a platform for consultation. The House of Habsburg (Charles the Fifth) inherited the Burgundian territories, and The Netherlands subsequently became part of Spain under Philip the Second. Between 1568 and 1648, an 80-year war of independence was fought, resulting in the establishment of the Republic of the United Netherlands, a loose federal political structure. During the period of the Republic (1568-1795), the provinces and the local and regional waterships controlled water management. The federal government (the State Council and the Prince of Orange) only interfered for military purposes. Only in 1754, a general inspector for the Rhine and the streams in Holland was appointment by federal government in The Hague. The provinces resisted any form of centralization. The federal government was too weak, and often divided to centralize authority.

A series of major sea surges between 1400 and 1600 resulted in great land losses. This in turn led to a major shift in the distribution of water between the branches of the Rhine; the IJssel slowly silted up whereas the Waal discharged more and more water. This process was accompanied by a number of river floods. In addition, climate all over Western Europe worsened from about 1480 on (the beginning of the Little Ice Age). In the second half of the 15th century, a new phenomenon emerged: ice-blocking. Sand banks in and dikes along the river hampered discharge of ice which occasionally resulted in huge dams of ice behind which melt water accumulated. Ice-blocking was caused by a combination of gradual cooling, and rivers becoming narrower and windier. The river also became more shallow, as sediments were only dropped between the dikes. Consequently, discharge capacity was reduced; flood risks increased. The land behind the dike continued to settle and subside, and even faster with the introduction of novel draining techniques such as the windmill and sluices in the 17th century. Dikes grew higher and higher. Consequently, the pressure on the dikes increased, and floods became more frequent and more severe. Secondary protection, notable seepage quays and sideways diversions, had to be installed.

Another form of secondary protection, the cross-dike, was introduced by the end of the thirteenth century. An early example (1284) is the *Diefdijk* between the rivers Lek and Linge, between Culemborg and Leerdam (cf. Figure 3). Cross-dikes do not protect directly against river floods, but against dike bursts upstream. This reduced damage downstream, but enlarged it upstream, in the east. This was not particularly in the interest of the people in the eastern areas. On occasion, cross-dikes needed

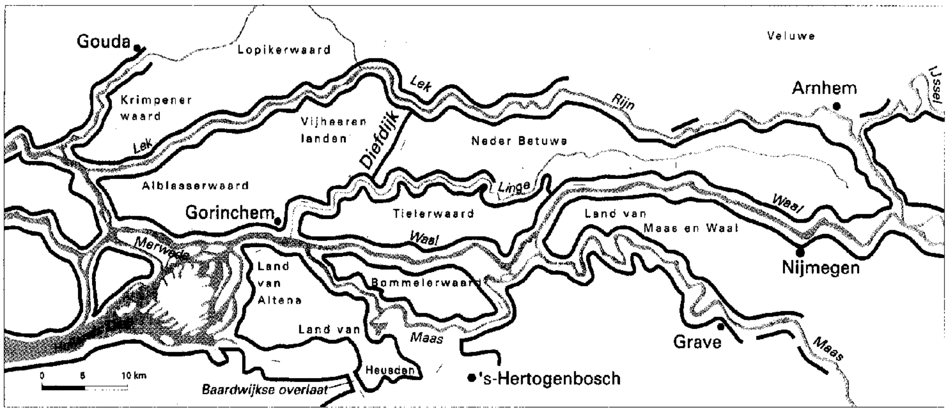

Figure 3. The situation along the Rhine and the Meuse around 1750. Fat lines depict dikes. The *Diefdijk* protected the *Vijfheerenlanden* and the *Alblasserwaard* against dike burst in the *Neder Betuwe*.

to be watched to prevent piercing. Obviously, the resulting atmosphere was not the most fertile conceivable for cooperative or coordinated flood control.

The interaction between climate and society was confounded. Climate change (i.e., the Little Ice Age) and the cumulative effects of inadequate management worked together to increase flood hazards.

Dike maintenance was the duty of the land owners whose land was protected by the dike. The duty was divided according to the amount of land, and the relative cost of dike maintenance (sharply bending dikes are more expensive to maintain than straight ones). Commons are shared property, so the dike duty was shared accordingly. Cities were exempted from dike maintenance. Because of the link between land ownership and dike maintenance, properties were assessed in the 'dike roles'.[*]

Dike control was in the hands of the 'dike chair', that consisted of an executive, the 'dike count'[**], a college of judges,[***] and an administrative body,[‡] responsible for the dike roles. The dike chair acted on behalf of, and was appointed by the land lord. The dike count inspected the dikes three times per year, in spring, summer and fall. During the spring inspection, the necessary reparations were established. The land owner had to take care of these. In the summer inspection, it was checked whether the reparations had taken place. Severe fines were the share of the negligent. In addition, labor needed to be hired to repair the dike while the dike chair resided in the inn nearby. Of course, all expenses were to be paid by the land owner, although the dike count was willing to lend him the money, at a 100% or 200%

[*] In Dutch: *dijkrollen*.
[**] In Dutch: *dijkgraaf*
[***] In Dutch: *heemraad* that could be transcribed as 'yard council'.
[‡] In Dutch: the *dijkschrijvers*, or 'dike writers'.

interest rate. Land owners not seldom went bankrupt as a result. During the fall inspection, the additional dike enforcements needed for the winter were checked.

Enforcement of water management was even more harsh in times of emergency. Additional dike inspections were carried out. Although the dike count could raise extraordinary taxes (e.g., in cities), a large part of the costs of dike maintenance and repair had to be borne by the land owner. In case the land owner was incapable of bearing these costs, his properties would be sold. The land owner would often be forced to leave the area (although he may well have left voluntarily). Should the properties be insufficient to cover the costs of dike restoration and maintenance, any part of the land owner's former property – regardless of who now owned it – could be claimed by the dike count to cover the costs of dike restoration and maintenance. Note that, despite the dike roles, land transactions were not as well documented as nowadays. A committee of seven neighbors of the deficient land owner were to decide on current and past properties. This, of course, occasionally led to social tensions. The dike count was not seldom in the best position to buy the land of the deficient land owner. The lack of accountability of the dike chair led to occasional abuse. Indeed, many large landowners of later days had dike counts as their ancestors.

Not only did land property imply dike maintenance, dike building also implied land property. New land along the river banks belonged to the owner of the adjacent old land. Hence, it was profitable to protect the new land as well; indeed, such activities could be defended as dike reinforcement. New land in the river bed was the property of the land lord. To raise funds, entitlements to reclaim this new land were often sold. As a result, water discharge capacity decreased, pressure on dikes increased, and the river became windier and narrower, which stimulated ice blocking and hampered shipping. This was known (at least from 1602 onwards), but no one had the power to counteract it.

Between 1750 and 1850, The Netherlands was tempted by a series of extremely serious river floods. River floods now dominated sea floods on the political and public agenda.

Over the years, the Waal discharged more and more of the Rhine water, at the expense of the Netherrhine and IJssel that almost fell dry. The IJssel in particular was a major transportation route. The causes for this redistribution are complex. Among them are failed attempts to force the Rhine back into the Netherrhine. Interestingly, one of the main reasons for re-establishing the discharge of the Netherrhine was national defense. In 1672, the water line failed to protect against the French invaders because of lack of water in the Netherrhine.* The situation only improved after the mouth of the IJssel was improved (after 1705) and the Pannerden Canal was opened in 1707 (cf. Figure 4). The latter project was the first move towards *Rijkswaterstaat*, the national water board.

* Deliberate flooding of polders was a common defense strategy in The Netherlands, officially abandoned after World War II. Flooded land hampered, sometimes stopped enemy armies.

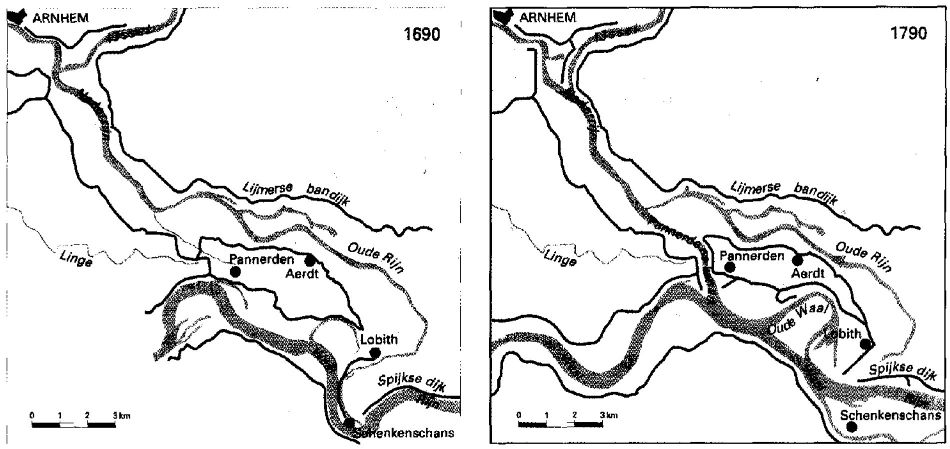

Figure 4. A dangerous situation emerged around 1690 because the Waal discharged 90% of the water of the Rhine. A lot of improvements were implemented, of which the Pannerden Canal was the most important. The situation was under control around 1790.

The Pannerden Canal aimed to alleviate the water shortage in the Netherrhine and IJssel, and to reduce the flood risk along the Waal. It was an overwhelming success. The canal shifted the major flood risks from the Waal to the IJssel and the Netherrhine. The water distribution was still unstable, however. Only by 1800 was this problem under control. After long negotiations and under Prussian pressure, the provinces of Gelderland, Utrecht and Overijssel jointly implemented structural improvements at a large scale, which stabilized water distribution. Two positive effects emerged from this. Firstly, the confidence of the engineers was enhanced. Secondly, awareness grew that cooperation and coordination were in the general interest.

Against the background of the Little Ice Age, land reclamation and silting up, the three main problems were the bad condition of the river beds and dikes, the unstable distribution of the water between the river branches, and the insufficient number of river mouths. The dikes were the result of centuries of ad hoc protection, land reclamation, and dike reparation. The dike system that had grown over the centuries was all but optimal for water control. The dikes themselves were often weak and low. The river beds were too narrow because of land reclamation, and too shallow because of silting up. The Rivers Waal and Meuse shared their mouth, so that high water in the Rhine led to floods along the Meuse in spring and winter. The shared last part of the Waal and Meuse, the Merwede, passes along the Biesbosch, a coastal wetland. More and more water was discharged through the Biesbosch, so that the Merwede silted up. However, the Biesbosch occasionally froze in wintertime, blocking the water discharge.

Plans for flood control abounded. Further enforcement of the dikes was considered expensive and ineffective. A popular alternative was sideways diversions, canals connecting streams that should lead to a more even distribution of flood discharge. In addition, flood water was to be led to relatively lightly populated and unproductive land. This shifted rather than solved the problem. A more structural approach was due to Cornelis Velsen in 1749. The flood plains should be widened and freed from the many obstacles (causing ice-blocking). The rivers should be straightened to speed up water discharge.* Two new mouths, one for the Waal and one for the Meuse, should be created. Technical, financial, and organizational problems prevented implementation of these plans for about a century. It required a whole new political structure to establish these improvements.

The interaction between climate and society was again virtually absent. Climate was harsh but more or less constant during the Little Ice Age. Management and management failures caused changes in flood hazards.

The loose structure of the Republic of the United Netherlands ceased to exist in 1795. It was replaced by the centralist Batavian Republic, resorting under Napoleonic France, and later (1815) by the Kingdom of The Netherlands. Many things changed. A central agency for water control was established that initially focused on early warning, relief, and restoration. The waterships retained control but were given directives from The Hague. The French law, which shifted dike maintenance from a part of a dike (i.e., an individual land owner) to an entire dike system (i.e., the population protected by it), was one of the few Napoleonic laws that were not retained by the Kingdom, under pressure of the waterships.

Structural improvements were still only studied and discussed. One committee after another was formed, but little happened. The major impediments were the high costs and miserable state of government finances, the dense population resisting large infrastructural works, the fear of a redistribution of flood risks from Holland and Utrecht to the eastern and southern provinces, and the political instability resulting from the resistance against the formation of a centralist state and from the independence war of Belgium.

Some progress was made, however. Private dike maintenance was replaced by public maintenance in 1838, despite resistance at the countryside, where floods were regarded as acts of God and taxes as an invention of if not the devil than untrustworthy townsfolk.* Maps of the river beds were made, so that illegal land reclamation could be combated.

The big turnaround came in 1850. During the period 1820 to 1850, handicraft engineers were gradually replaced with scientifically (and military) trained ones; after the reorganization of the corps of engineers in 1849, the latter took over control. 1848 brought about a new constitution. In that year, a stable government was finally established under prime-minister Thorbecke, and state finances were reorganized. In addition, the transport sector, strongly supported from Germany,

* Note that water discharge is so fast nowadays that drought emerged as a problem in the south of the Netherlands.

* The change in attitude of Dutch people is remarkable, even for a period of 150 years.

pressed hard for navigable waterways, as demand for transport increased with industrialization.

Eventually, structural improvements were rapidly planned and implemented. The plans were based on the success story of the river Elbe in Germany. The river beds were straightened and deepened (with steam power). Dikes were reinforced. New mouths were dug. Sideways discharges were closed. Initially, the improvements met resistance that, however, rapidly waned after the floods of 1855 and 1861. Problems with draining were solved with the introduction of steam mills. The works lasted for ninety years. Around 1900, intensification took place because of river transport. The last great flood occurred in 1926. The last sideways discharge was closed in 1943.

The interaction between climate and society were confounded. Climatic conditions gradually improved, but so did political, technical and economic circumstances. Flood hazards decreased as a result.

3. The Present and Future of River Floods

At the moment, flood risk appears to be on the rise again, witnessing the series of Meuse floods of the last 15 years and the near-flood of the Rhine early 1995. Reasons are decades of relative negligence of the dikes and the river bed, changes in the watershed, increasing human activities near the river, and perhaps also climate change. Since it is now recognized that flood control does not meet its legal requirements, strengthening of flood control is underway. The law says that protective measures should withstand the 1/250 flood along the Meuse in South Limburg, and the 1/1250 flood for other rivers. Flood standards are decided by a committee, and regularly evaluated and adjusted to changed circumstances. Circumstances that may change include flood hazards, risk perceptions, and management styles (Van der Grijp and Olsthoorn, 1998).

Interestingly, climate change is regarded in these plans. This is as it should be: long-term infrastructural investments should be looking to the future rather than to the present. Table I shows the current annual average damage, how this may change with climate change and urbanization, and how flood control affects average damages. A modest change in climate (+2°C and +10% precipitation in winter-time) may more than double flood damages. However, intensified flood control may cut damage by a factor of 10. Similar sensitivities were found for the Thames and the Seine (Penning-Rowsell et al., 1996).

4. Conclusions

What does this all mean for thresholds and response functions? Thresholds are closely related to indicators which describe a system’s health. The threshold is

TABLE I

Annual average expected damage from Meuse floods in the year 2050 (Dfl. million)

	Now[a]	Urbanization[b]	Climate[c]	Urbanization and climate change[b+c]
Current[d]	9.9	10.6	21.8	27.1
Deepening summer bed	0.7	0.7	1.5	1.9
Wildlife area development				
(1)	0.6	0.7	1.4	1.8
(2)	0.9	0.9	1.9	2.4
(3)	3.3	3.6	7.3	9.1
Building quays	3.5	3.8	7.4	9.6

[a] No change in hazard; note that the assets at risk are assumed to remain as they were in 1993 in all scenarios.
[b] A 5% increase in urbanization.
[c] A 10% increase in winter precipitation and a 2°C increase in temperature.
[d] No additional risk management.
Source: Penning-Rowsell et al. (1996).

then the value that indicates that the system is in alarmingly poor health. Indicators and thus thresholds are sufficient statistics, whose main merit lies in their simplicity. Looking at the history of river floods in The Netherlands, a simple indicator does not seem obtainable. The issue evolved from ‘no problem’, to ‘prime national threat’, to ‘under control’, to ‘re-emerging’ (cf. Figure 5). The evolution was determined by, amongst others, climate, technological development, foreign policy, transportation, institutional changes, and risk perceptions. A proper indicator would not be simple, thus losing its main merit. The influence of climate on changes in flood hazards was indirect, virtually absent, or confounded with social dynamics. A proper indicator would neither be a function of only climate, thus rendering it improper as a guide for greenhouse gas emission reduction.

A response function would suffer similar drawbacks. It also conveys a message of an active climate impacting a passive society. The above story made clear that society is not passive, but in fact often changes faster and more influential than climate. Also, adaptation, although successful in the short run, proved problematic in the long run, and got entrapped in its own institutional and technological dynamics. A simple response function would likely miss some crucial changes, particularly in the longer run. A proper reduced form model would be a function of society and past adaptation just as much as of climate. A reduced form model would also be complex. It is unfortunate that coupled complex models of interactions between weather hazards and society are rare. These would have to be developed first, before

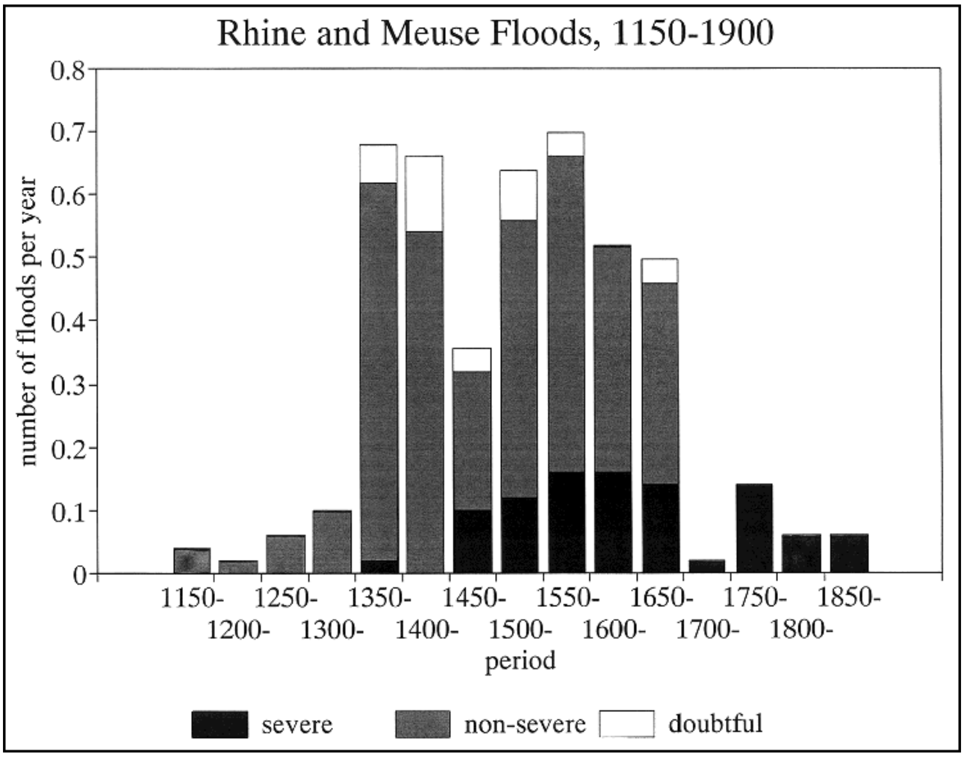

Figure 5. A summary of thousand years of river floods in the Netherlands.

reduced form models can be derived. This, alas, is the sobering state of the art in the field of climate change and extreme weather events.

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References

Downing, T.E., Olsthoorn, A.A. and Tol, R.S.J.: 1996, *Climate Change and Extreme Events – Altered Risk, Socioeconomic Impacts and Policy Responses*, Institute for Environmental Studies, R96/04 and Environmental Change Unit, Research Report 12, Vrije Universiteit and University of Oxford, Amsterdam and Oxford.

Gottschalk, M.K.E.: 1971, *Sea Surges and River Floods* (three volumes), Assen (in Dutch).

Langen, A.: 1995, 'History of River Floods in the Dutch Rhine Delta', Institute for Environmental Studies W95/16, Vrije Universiteit, Amsterdam (in German).

Langen, A. and Tol, R.S.J.: 1996, 'A concise history of riverine floods and flood management in the Dutch Rhine Delta', in Downing, T.E., Olsthoorn, A.A. and Tol, R.S.J. (eds.), *Climate Change and Extreme Events – Altered Risk, Socio-economic Impacts and Policy Responses*, Institute for Environmental Studies and Environmental Change Unit Research Report, Vrije Universiteit and University of Oxford, Amsterdam and Oxford, pp. 129-138.

Penning-Rowsell, E., Handmer, J. and Tapsell, S.: 1996, 'Extreme events and climate change: floods', in Downing, T.E., Olsthoorn, A.A. and Tol, R.S.J. (eds.), *Climate Change and Extreme Events – Altered Risk, Socio-economic Impacts and Policy Responses*, Institute for Environmental Studies and Environmental Change Unit Research Report, Vrije Universiteit and University of Oxford, Amsterdam and Oxford, pp. 97-128.

Stol, H.: 1993, *Rising Water, Falling Land – History of the Netherlands and the Water*, Utrecht/Antwerpen (in Dutch).

Van de Ven, G.P. (ed.): 1993, *Liveable Lowland – History of Water Control and Land Reclamation in The Netherlands*, Utrecht (in Dutch).

Van der Grijp, N. and Olsthoorn, A.A.: 1998, 'Case study international framework for the management of the rivers Rhine and Meuse in the Netherlands', SIRCH Working Paper, Institute for Environmental Studies, Vrije Universiteit, Amsterdam.

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